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Faculteit der Sociale Wetenschappen

The Influence of Navigational Experience and Living Area on Navigation Ability

Michelle Knook

Master Thesis Clinical Neuropsychology
Faculty of Behavioural and Social Sciences – Leiden University
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Student number: s2091364
Daily Supervisor: Ineke van der Ham, Health, Medical and Neuropsychology Unit; Leiden University
CNP-co-evaluator: Rebecca Schaefer, Health, Medical and Neuropsychology Unit; Leiden University

Abstract

Navigation ability strongly varies among people and it is still unclear what contributes to these differences. Recent studies have begun to disclose the underlying mechanisms of the differences between people in navigation ability. The current study was conducted to investigate the influence of living area and navigational experience on navigation ability to examine possible factors that contribute to the differences between people in navigation ability. Navigation ability was defined to consist of three categories, i.e., knowledge of landmarks, locations and paths. The expectation was that participants with more navigational experience and from urban environments would perform better on the allocenric aspects of navigation ability in comparison with participants with less navigational experience and from rural environments. 3470 participants filled in a demographic questionnaire and performed a navigation experiment containing the three categories (and subcategories) of navigation ability. Results showed that participants with the least navigational experience scored lower than participants with more navigational experience on the allocentric location-based aspect of the navigation experiment. The living area of the participants did not have an influence on the navigation experiment. Together, these findings suggest that navigational experience can improve some aspects of navigation ability and is a substantial factor in explaining individual variation in navigation ability.

Navigation is an ability that occurs every single day and we need it every day to move from one place to another. We use navigation when we go to work or visit a friend in another city, but even inside our own house we need navigation to go from the bedroom to the bathroom. Navigation is very important, which is also shown in the growing interest and research on this ability. Wolbers and Hegarty (2010) describe spatial navigation as 'the ability to maintain a sense of direction and location while moving about in the environment'. As people move in the environment, they perceive surrounding space and acquire knowledge about that specific environment (Ishikawa & Montello, 2006). A notable feature of navigation is that it strongly varies among people. Some people are very good at finding the way in a new town for instance, while other people have difficulties with it. There is still little information about the cause for these differences. What we do know is that spatial navigation consists of a complex collection of cognitive processes involving basic perceptual and memory-related processes and that they are based on distinct spatial representations (Wolbers & Hegarty, 2010; Wolbers, Weiller & Büchel, 2004). People can differ in the kind of representations they use when they are navigating, which can cause the individual variation in navigation.

Siegel and White (1975) were one of the first who proposed a theoretical framework explaining the development of spatial representations in navigation ability. In their framework they proposed three different types of representations, i.e., landmark knowledge, route knowledge and survey knowledge. Landmark knowledge is the ability to navigate based on the knowledge of landmarks. Landmarks can be (famous) buildings or environmental scenes like landscapes and they are stored in memory and recognized when perceived (Montello, 1998). Route knowledge is the order in which landmarks occur along a route and survey knowledge is the ability to interpret the metric distances and directions of paths (Siegel & White, 1975). Siegel and White’s framework was very influential in the scientific literature, but many new studies have been added to the literature since the framework was proposed (Ishikawa & Montello, 2006). Claessen and Van der Ham (2017) have shown that modifications to the original proposal are in order. In their systematic review of neuropsychological case studies they have shown that navigation ability consists of three different categories of navigation. These categories can be used to assess the differences between people, because these categories are related to three types of representations relevant for navigation ability, i.e., knowledge of landmarks, locations and paths. Here, knowledge of landmarks is the same as proposed by Siegel and White (1975). Location-based navigation is the knowledge of landmark locations and how these places relate to each other (Claessen & Van der Ham, 2017). Location-based navigation can be absolute (allocentric), which means information about the location of one object relative to the location of another object (Aguirre & D’Esposito, 1999). Location-based navigation can also be relative (egocentric), which refers to the information about the location of one object relative to yourself. The last category is path-based navigation, which contains route knowledge and survey knowledge of Siegel and White’s framework (1975). According to Ishikawa and Montello (2006), survey knowledge can also be called a cognitive map, a scaled representation of the layout of the environment. This allows an individual to infer spatial relations between any two places irrespective of his own position (Wolbers et al., 2004).

The model of Claessen and Van der Ham (2017) about the functional structure of navigation ability makes it possible to understand differences between people in navigation, because people use the three categories of navigation differently when they are navigating. One possible cause for the preference to use one category more than another category is navigational experience. Navigational experience develops through repeated exposure to an environment (Ruddle, Payne & Jones, 1997). Experience can be important in the development of navigation ability (Montello, 1998). The dominant framework of Siegel and White (1975) explains that developing spatial representations begins with the initial stage of landmark knowledge. People are equally able to know and update their position and orientation on the basis of landmarks (Wolbers & Hegarty, 2010). From the initial stage of landmark knowledge, people move to a stage of route knowledge to an ultimate stage of survey knowledge (Montello, 1998; Siegel & White, 1975). This means that survey knowledge is the most sophisticated and develops with more spatial and navigational experience. There are many studies that investigated the role of navigational experience on navigation and the survey knowledge subcategory of navigation. Maguire et al. (2000) discovered that taxi drivers in London, who spent their time navigating the city, have significantly greater volume of the posterior hippocampi. The hippocampus plays an important role in spatial memory and navigation (O'Keefe & Nadel, 1978). This study shows that increasing exposure to an environment and thus navigational experience can cause changes in the structure of a healthy human brain (Maguire et al., 2000). Woollett & Maguire (2010) have shown that navigational experience not only affects the human brain, but also the ability to learn a new environment. They discovered that taxi drivers were able to plan and execute routes and that they were good at creating and using a survey-like representation of a new town. The larger volume of the posterior hippocampus of London taxi drivers can cause taxi drivers to be better at possessing a survey-like representation of a town, also called a cognitive map. This survey-like representation can be viewed as the survey knowledge subcategory of path-based navigation in the model of Claessen and Van der Ham (2017). Similar to taxi drivers, pilots spend their working time navigating (Sutton, Buset & Keller, 2014). Pilots can form more accurate cognitive map representations in comparison with non-pilots. However, non-pilots rely more on route-based representations or less accurate cognitive map representations. This can be interpreted as pilots being better at survey knowledge path-based navigation and non-pilots being better at route knowledge path-based navigation of the model of Claessen and Van der Ham (2017). From these studies we can expect that people who spent their working time navigating and are extensively exposed to environments every day, are better at the survey knowledge subcategory of path-based navigation in comparison with people without this navigational experience. While a survey-like representation of a town is allocentric, it can also be expected that people with navigational experience are also good at the allocentric location-based navigation.

Repeated exposure to navigating and to an environment, i.e., navigational experience, thus can be of influence on navigation. It can be argued that repeated exposure to an urban environment differs from repeated exposure to a rural environment. Living in an urban environment can, just like the taxi drivers, be the cause of a better allocentric and survey representation. Studies support this, by reporting that home-range size has indeed an influence on spatial abilities (Ecuyer-Dab & Robert, 2004; Jones, Braithwaite & Healy, 2003). Home range is the area travelled over by individuals to achieve their daily routine activities, also called living area (Ecuyer-Dab & Robert, 2004). The range size hypothesis predicts that sex differences in spatial abilities will be found in species where males have larger home ranges than females (Jones et al., 2003). In former times, males had larger home ranges because they had to cover a larger area in order to father offspring and the females had to stay home to take care of the children. This caused men to have better spatial and navigational abilities than women (Ehrlich, Levine, & Goldin-Meadow, 2006; Padilla, Creem-Regehr, Stefanucci & Cashdan, 2017; Uttal et al., 2013). It is shown that nowadays, people with a larger home range size still have a more precise knowledge of their environment, irrespective of sex (Stephan, Jäschke, Oberzaucher & Grammer, 2014). Living in a larger home range size has a positive influence on the accuracy of cognitive maps and thus mental representations of a town. This can also be linked to people living in an urban environment where the home range size and thus the living area is larger. We therefore expect that living in a larger home range will cause better spatial abilities and therefore better navigation abilities and more spatial experience than people living in a rural environment for both men and women.

Despite the many studies on the role of navigational experience, there are not many studies that combine the role of navigational experience and living area to explain differences in navigation ability between people. In the current study we aimed to study the influence of navigational experience and living area on navigation ability in a large heterogeneous population to investigate if this can explain the individual variation in navigation ability. Navigation ability was in this study subdivided into the three main types of navigation from Claessen and Van der Ham (2017), i.e., landmark-based, location-based and path-based navigation. Looking at previous studies, it can be expected that landmark-based navigation is acquired first when navigation ability develops and that it does not improve as a function of experience, according to the framework of Siegel and White (1975) and the study of Evans, Marrero and Butler (1981). Therefore we expected that landmark-based navigation scores would be the same for people with navigational experience and living in an urban environment and people without navigational experience and living in a rural environment. According to Evans et al. (1981) the location of the landmarks emerges after landmark knowledge, but there is still no conformation if locations develop before paths (Gärling, Böök, Lindberg & Nilsson, 1981). But what is known is that human beings first learn the relative position of landmarks in space, which is egocentric (Evans et al., 1981). Because of this, we expected that there would be a difference in scores for allocentric and egocentric location-based navigation. For egocentric location-based navigation we expected that people without navigational experience and living in a rural environment would have a higher score than people with navigational experience and living in an urban environment. Because the absolute position of landmarks is more difficult to obtain, we expected that allocentric location-based navigation scores would be higher for people with navigational experience and living in an urban environment than for people without navigational experience and living in a rural environment. According to Montello (1998), survey knowledge is the most difficult aspect of navigation to acquire and requires experience. Therefore we expected that survey knowledge scores would be higher for people with navigational experience and living in an urban environment. While route knowledge develops before survey knowledge and requires no experience, we expected that route knowledge scores would be higher for people without navigational experience and living in a rural environment.

If landmark-based navigation scores are not the same for participants with experience and living in an urban environment and participants without experience and living in a rural environment, this would show that landmark-based navigation is not necessarily the first and easiest aspect of navigation and that the framework of Siegel and White (1975) is incorrect. Furthermore, if allocentric location-based navigation and survey knowledge navigation scores are not higher for people with experience and living in an urban environment, one could argue that this could be because people living in an urban environment have everything nearby. All places with high functional importance are more often close to home in comparison with a rural living area (Stephan et al., 2014). People living in a rural environment have to travel more to go to places and this could cause them to navigate more and have more experience and therefore have better scores on the allocentric location-based navigation and survey knowledge navigation.

In summary, despite the many studies about navigation, there is still much to be discovered with regard to individual variation in this ability. This study was designed to contribute to a further understanding of how experience and living area can have an influence on navigation ability. If we could outline the effects of living area and navigational experience, this could play a role in possible improvements in navigation ability.

Methods

Participants

A total of 3470 participants took part in the experiment. The study sample consisted of 2155 women, 1302 men and 13 participants described themselves as not male or female. Participants ranged from the age of 12 and up and varied in living area, education and navigational experience. Since the Netherlands is subdivided into different provinces, Figure 1 shows the descriptive statistics of the study sample by province. This study was part of the online public experiment for 'Weekend van de Wetenschap' in the Netherlands. People present at the 'Weekend van de Wetenschap' could participate in our study if they met the inclusion criteria. People who were not present at the 'Weekend van de Wetenschap' could do the experiment at home by going to www.navigerenkunjeleren.nl and by doing the experiment. All participants had to speak Dutch since the instructions of the experiment were only in Dutch. Participants with a history of neurological or psychiatric problems and participants younger than 12 years old were excluded from the study. All participants gave informed consent to participation in this study. Children younger than 16 years old needed their parents' permission to participate. There was no compensation given for participation.

Figure 1. Descriptive statistics of the study sample by province

Measures

The experiment was performed on a computer, either at home or in a quiet room at the ‘Weekend van de Wetenschap’. Before the experiment started, participants were informed about the ethics of the study and they had to give informed consent. After this, participants first had to fill out a demographic questionnaire about age, gender (male, female or other), education (basisonderwijs, LBO, VMBO, MBO, HAVO, HBO, VWO or WO), living environment (urban or rural and which province) and navigational experience. For navigational experience participants were asked how frequently they travelled to a new place (never, several times a year, several times a month, weekly or more). Within this questionnaire there were also three questions about navigation ability taken from the Wayfinding Questionnaire (Van der Ham, Kant, Postma & Visser-Meily, 2013). Participants had to fill in the extent to which the questions applied to them on a 7-point Likert scale, ranging from 1 (“not applicable to me at all”) to 7 (“totally applicable to me”). The questions were formulated as statements, i.e., ‘I usually can remember a new route after I passed it once’, ‘I am afraid to get lost in a foreign town’, ‘I am good at estimating how long a route will take in a foreign town when I see the route on a map’. After the demographic questionnaire, a navigation experiment (developed by M. van der Kuil) was given to participants to measure their navigation abilities. In this experiment participants were shown a video of a route leading to a spaceship and on this route several landmarks were shown. Beforehand participants were asked to memorize as much as possible of the video. After this video there were five tasks which represented the three main types of navigation and their subdivisions based on the model of Claessen and Van der Ham (2017).

For the landmark-based navigation task, participants were presented with eight images of landmarks that they had encountered in the virtual environment (targets) or landmarks that they had not encountered in the environment (distractors). Participants had to select a green button if they had seen the landmark and a red button if they had not seen the landmark, as is shown in Figure 2. For every participant, the order in which the landmarks where shown could differ. The landmark-based navigation task consisted of eight multiple choice questions, where a total score of 8 could be obtained.

Figure 2. Example of the landmark-based navigation task

For the egocentric location-based navigation task, participants had to select the correct direction to the spaceship as seen from the landmark presented. Participants could select the right direction from a list with six possible directions by clicking on the right direction as shown in Figure 3. This task consisted of four multiple choice questions. These four questions were randomly chosen from a total of eight questions. Participants could obtain a total score of 4 if they selected all the right directions.

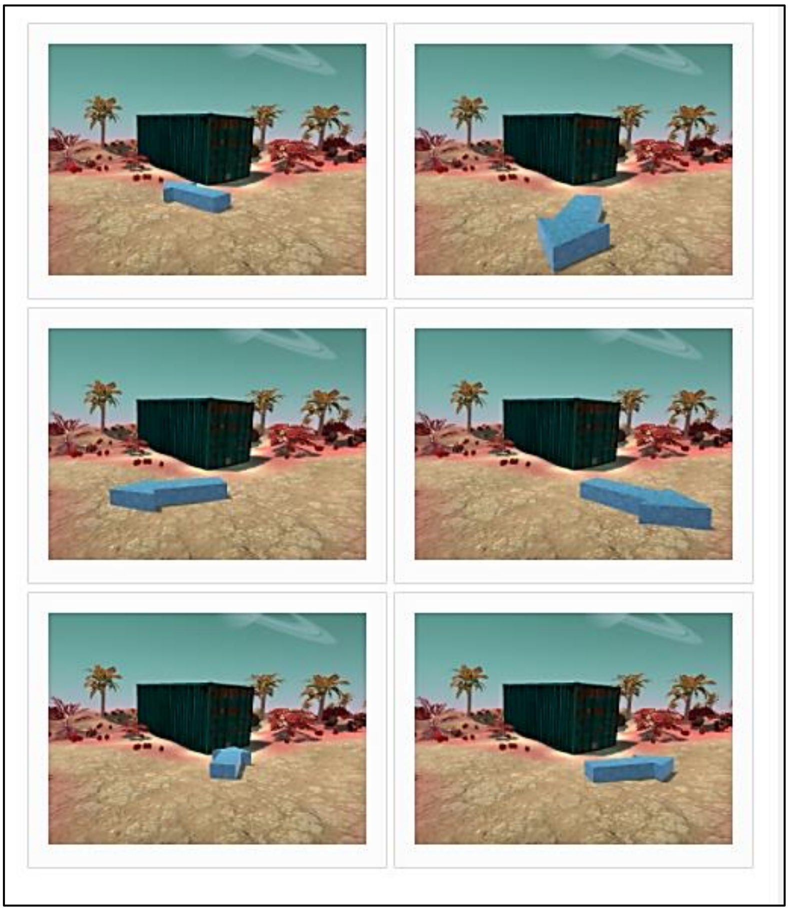

Figure 3. Example of the egocentric location-based navigation task

For the allocentric location-based navigation task, participants had to point out landmark positions on a map. Participants were shown a landmark that they had encountered in the virtual environment and a little map of the environment where they had to select the place where they encountered the landmark. This is shown in Figure 4. Participants could choose from four possible places on the map, marked as A, B, C and D. This task consisted of four questions, which were randomly chosen from eight questions. Participants could obtain a total score of 4 if they selected the correct places on the maps.

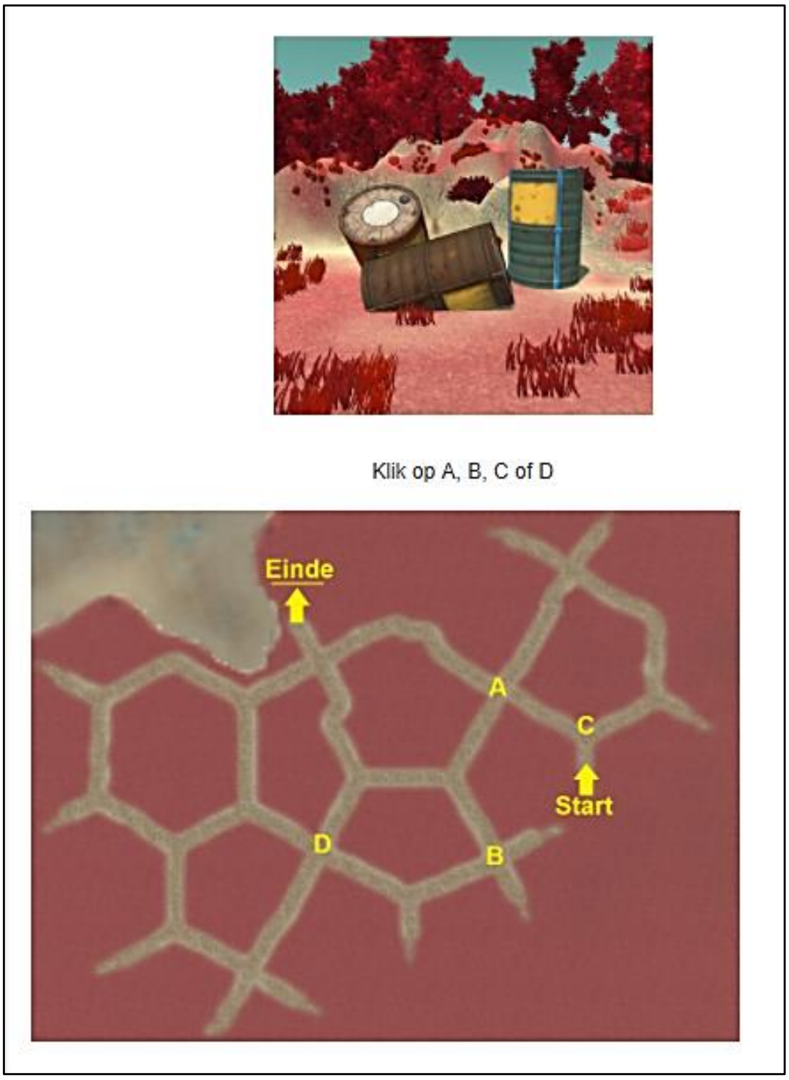

Figure 4. Example of the allocentric location-based navigation task

For the route knowledge (path-based) navigation task, participants indicated how the route that they saw on the video continued from the landmark presented. Participants were shown the images of the landmarks they had encountered and had to select if the route continued to the right, the left or straight on, as shown in Figure 5. Participants selected the right direction by clicking on the arrow that showed the right direction. This task consisted of four multiple choice questions, randomly selected out of eight questions. From the eight questions, five were classified as Easy, as participants had to select if the route continued to the right or to the left. Three out of eight questions were classified as Hard, as participants had to select if the route continued to the right, the left or straight on. Every participant received one Hard question and three Easy questions. A total score of 4 could be obtained.

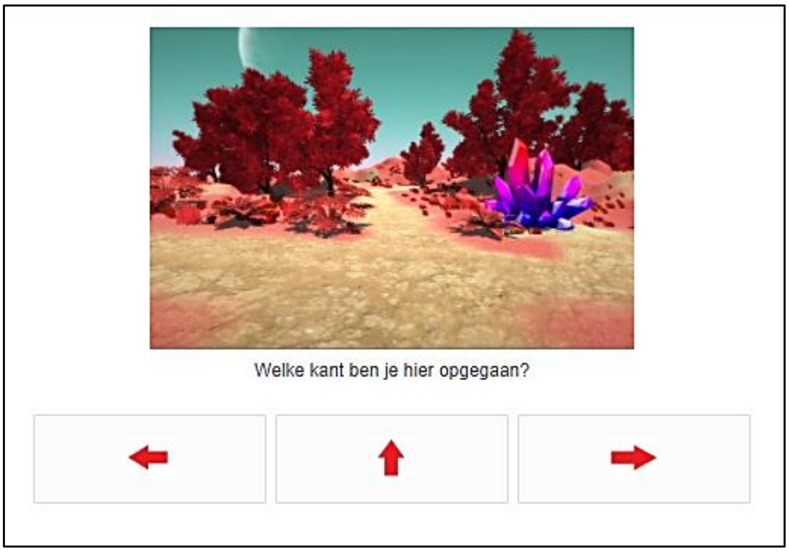

Figure 5. Example of the route knowledge path-based navigation task

For the survey knowledge (path-based) navigation task, participants had to select two out of three landmarks which were thought to be closest together. Participants were shown three images of landmarks that they had encountered in the environment and they had to select the two images that were thought to be closest together, as shown in Figure 6. This task consisted of four questions randomly chosen out of eight questions. Participants could obtain a total score of 4 on this task if they answered the questions correctly.

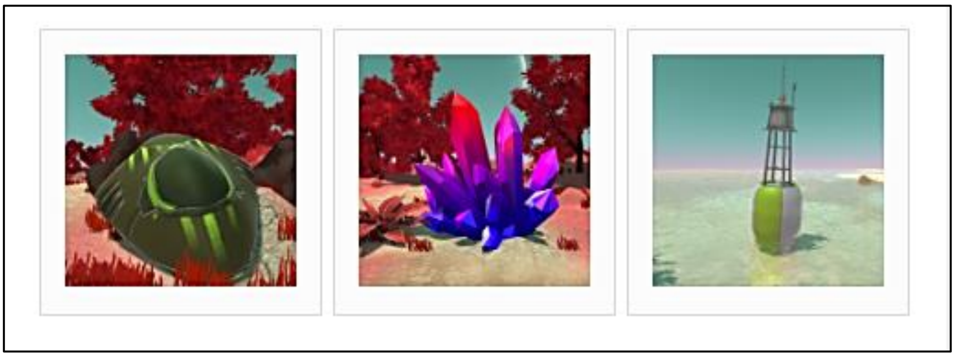

Figure 6. Example of the survey knowledge path-based navigation task

After the navigation experiment was finished, no further data was collected. However, participants received a personal navigation style, showing if they had a landmark-based, egocentric-based or allocentric-based navigation style. Participants could read information about their navigation style and tips and advice on how to improve their navigation ability. After this, participants had the choice to finish the experiment or to complete the Wayfinding Questionnaire about navigation ability (Van der Ham et al., 2013).

Design

The current study was a cross-sectional study, containing an online experiment where participants were asked to do tasks on the computer. We took into account the between subject factors of gender, education, age, living area, navigational experience and subjective navigation performance together with a virtual game where navigation ability was measured. Each participant performed the demographic questionnaire and subsequently the same tasks of the navigation experiment. After the demographic questionnaire, every participant started with the questions about landmark-based navigation. After the landmark-based navigation questions, the order of the questions could differ. The following tasks were allocentric and egocentric location-based navigation and route knowledge and survey knowledge path-based navigation. All participants performed the experiment only once.

Procedure

All participants were tested individually and were told at onset that they took part in a study about navigation styles. People who were present at the Weekend van de Wetenschap and who wanted to participate in the experiment were asked to go to the website www.navigerenkunjeleren.nl. People who were not present at the Weekend van de Wetenschap could participate on their own initiative by going to the website www.navigerenkunjeleren.nl. Firstly, participants were asked to complete the first questionnaire. In this questionnaire, participants first had to fill in if they were older than 16 years old. When the participant was older than 16 years old he/she had to fill in two boxes: 1. Agreeing that the participant had read and understood the text. 2. Agreeing to participate with the experiment under the stated condition. When the participant was younger than 16 years old, the parents of the participant had to fill in the above two boxes. After these two questions, participants had to fill in a demographic questionnaire with questions about age, gender, education level, living environment, province and navigational experience. After the questionnaire, a navigation video would start. Participants were shown a video of a route taking place on a planet which lead them to a spaceship. Participants had to memorize what they had seen and after the video they were presented with five tasks. These tasks contained the separate aspects of navigation ability, based on Claessen and Van der Ham (2017). When the experiment was finished, the participants received their own score indicating how well they did on the tasks. They also received some tips on how they could improve their navigation skills and they got the option to proceed to a set of training exercises and to an additional questionnaire about wayfinding. From this point, no further data was collected. The data collection started the 20th of September 2017 and current analyses include data collected until the 17th of November 2017. Approval of the Committee Ethics Psychology was obtained.

Statistical analyses

Navigational experience and living area and their relationship with the five tasks of the navigation experiment were evaluated with SPSS version 22. The dependent variables were the five tasks of the navigation game, i.e., landmark-based navigation, location-based allocentric and egocentric navigation and path-based survey knowledge and route knowledge navigation. We performed a multiple analysis of variance (MANOVA) using a general linear model (GLM). This analysis could be used to evaluate the main effects of both navigational experience and living area and their interaction effects on the five tasks and the total score of the navigation experiment. In conclusion, post-hoc tests were performed to create insight in the directions of the effects the GLM showed. A Bonferroni correction was applied. Before the analyses were performed, Box's test of equality of covariance matrices was performed to check if the observed covariance matrices of the dependent variables were equal across the groups. For all analyses, a significance level of $\alpha = .05$ was used.

Results

A total amount of 3470 participants took part in the experiment. Table 1 shows the descriptive statistics of the study sample. Female participants were more represented in the sample in comparison with male participants. Table 1 also shows that more participants lived in an urban environment in comparison with a rural environment. Table 2 shows the demographic characteristics of the participants living in an urban environment and participants living in a rural environment. What is shown in Table 2 is that the average age between participants from rural environments and participants from urban environments was different. An Independent Samples T-Test with a non-pooled variance was performed to check if the difference in average age between urban and rural environments was significant. The Independent Samples T-Test showed that average age between participants living in a rural environment and participants living in an urban environment was significantly different with $p < .001$. Because of this, we used age as a covariate in our analyses.

Table 1

Descriptive statistics of the study sample

	Avarage age	Female/ Male/ Other	Experience never	Experience once a year	Experience once a month	Experience weekly	Urban/Rural
N	42.2	2155 / 1302 / 13	88	2222	978	182	2585 / 885
%		62.1 / 37.5 / 0.4	2.5	64	28.2	5.2	74.5 / 25.5

Table 2

Demographic Characteristics of the Urban and Rural Participants

	Urban	Rural
Gender (M/F/O) (%)	36.6/62.9/0.4	40/59.5/0.2
Average age	41.10	45.53
Experience (%)		
Never	2.4	2.8
Once a year	63.0	67.0
Once a month	28.7	26.7
Weekly or more	5.8	3.5

Note. M= male, F= female, O= other.

The MANOVA concerning living area and all five navigation tasks revealed that there were no significant main effects for living area on the five separate tasks of the navigation experiment, with an alpha-level of .05. However, there was a trend towards significance on the landmark-based navigation task ($F(3,3462) = 3.45$, $p = 0.06$), with an effect size of 0.00. A post-hoc test revealed that participants from a rural living area performed better than participants from an urban living area. There was no main effect found for the total score of the navigation experiment, when we combined the five tasks to look at the global navigation ability. Table 3 shows the mean scores and p-values for living area on the five tasks of the navigation game.

Table 3

Mean Scores and Standard Deviations Obtained by Urban and Rural on Each Navigation Task

	Urban		Rural				
Task	*M*	*(SD)*	*M*	*(SD)*	*F*	*p*	$n_p{}^2$
Landmark	6.81	(0.04)	6.92	(0.07)	3.45	0.06	0.00
Location Egocentric	1.21	(0.04)	1.22	(0.07)	F<1	0.87	0.00
Location Allocentric	1.76	(0.04)	1.71	(0.07)	F<1	0.82	0.00
Route knowledge	2.61	(0.04)	2.54	(0.07)	F<1	0.69	0.00
Survey knowledge	2.23	(0.04)	2.16	(0.07)	F<1	0.56	0.00
Total score	14.62	(0.12)	14.54	(0.21)	F<1	0.77	0.00

Note. MANOVA = multiple analysis of variance. *M* = Mean, *SD* = standard deviation , $\eta_p{}^2$ = partial eta squared.

The MANOVA focused on navigational experience showed that there was a significant effect of navigational experience on allocentric location-based navigation ($F(3,3462) = 9.70$, $p < .001$), with an effect size of .01. A post-hoc test was performed to create insight in the directions of the effect of navigational experience on allocentric location-based navigation. The post-hoc test showed that participants who never travelled to a new place scored significantly lower in comparison with participants who travelled once a year ($p < .001$), participants who travelled once a month ($p < .001$) and participants who travelled weekly or more ($p < .001$) on the allocentric location-based navigation task. These results were Bonferroni corrected. This means that participants with the least navigational experience scored significantly lower than the other three groups with more experience on the allocentric location-based navigation task. There were no significant differences between participants who travelled once a year, once a month or weekly or more. For the combined total score of the five tasks of the navigation experiment, we observed a significant difference between the four experience groups ($F(3,3462) = 2.80$, $p = 0.04$) with an effect size of 0.00. As is shown in Table 4, participants who never travelled to a new place had the lowest mean score in comparison with the other three experience groups, with in all cases $p < .001$. This shows that participants with the least experience scored significantly lower on the navigation experiment than participants with more experience. For landmark-based navigation, egocentric location-based navigation, path-based route knowledge and survey knowledge navigation no significant effects were found (*p* >.10 in all cases). Table 4 shows the mean scores and p-values for navigational experience on the five tasks of the navigation experiment.

Table 4

Mean Scores and Standard Deviations Obtained by Navigational Experience on Each Navigation Task

	Navigational Experience										
	Never		Once a year		Once a month		Weekly				
Task	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*F*	*p*	η_p^2
Landmark-based	6.52	(0.13)	7.00	(0.03)	7.02	(0.04)	7.00	(0.10)	2.11	0.10	0.00
Egocentric location-based	1.22	(0.11)	1.17	(0.02)	1.21	(0.04)	1.25	(0.09)	F<1	0.79	0.00
Allocentric location-based	1.21	(0.13)	1.85	(0.03)	1.88	(0.04)	2.01	(0.11)	6.44	0.00	0.01
Route knowledge	2.38	(0.12)	2.63	(0.03)	2.69	(0.04)	2.61	(0.10)	F<1	0.61	0.00
Survey knowledge	2.08	(0.13)	2.25	(0.03)	2.30	(0.04)	2.14	(0.10)	F<1	0.45	0.00
Total score	13.41	(0.35)	14.86	(0.07)	15.10	(0.11)	14.96	(0.29)	2.80	0.04	0.00

Note. MANOVA = multiple analysis of variance. *M* = Mean, *SD* = standard deviation , η_p^2 = partial eta squared.

The MANOVA showed no significant interaction effects for navigational experience, living area and the five tasks of the navigation experiment. However, there was a trend towards significance for route knowledge path-based navigation ($F(3,3462) = 2.33$, $p = .07$), with an effect size of .00. Participants living in an urban environment performed better on the path-based route knowledge navigation task when they travelled to a new place once a year, once a month or weekly in comparison with participants living in a rural environment, who performed better if they never travelled to a new place. Table 5 shows the p-values for the interaction effects on the five tasks of the navigation experiment.

Table 5

Interaction Effects of Living Area and Navigational Experience on Each Navigation Task

Task	*F*	*p*	$\eta_p^{\,2}$
Landmark-based	1.35	0.26	0.00
Egocentric location-based	F<1	0.51	0.00
Allocentric location-based	1.70	0.17	0.00
Route knowledge	2.33	0.07	0.00
Survey knowledge	1.76	0.15	0.00

Note. MANOVA = multiple analysis of variance.
$\eta_p^{\,2}$ = partial eta squared.

Discussion

The purpose of the present study was to examine the influence of navigational experience and living area on navigation ability in a large heterogeneous population to examine the differences between people in navigation ability. The expectation was that participants living in an urban environment and having more navigational experience would score better on the allocentric location-based navigation task and the survey knowledge path-based navigation task, while participants living in a rural environment and having less navigational experience would score better on the egocentric location-based navigation task and the route knowledge path-based navigation task. Scores on the landmark-based navigation task were expected to be the same for all participants.

Results showed that living area, i.e., urban or rural, had no influence on the navigation experiment and thus not on navigation ability. Unlike living area, navigational experience did have an influence on specific types of navigation ability, based on the model of Claessen and Van der Ham (2017). Participants with the least navigational experience, i.e., never travelling to a new place, scored lower in comparison with participants with more navigational experience, i.e., travelling to a new place once a year, once a month or weekly, on the allocentric location-based navigation task and on the total score of the navigation experiment.

These findings were approaching our expectations. According to Evans et al. (1981) landmark-based navigation does not improve as a function of experience and landmarks are used as initial anchor points in the environment. This is in accordance with our finding that participants with more navigational experience performed just as well as participants with less navigational experience. As for allocentric location-based navigation the results were as expected for navigational experience. People with less experience scored lower than people with more experience, which shows that allocentric location-based navigation is more sophisticated and is easier to use for people with more navigational experience. That egocentric location-based navigation scores did not differ between people with or without experience shows that human beings first learn the relative position of landmarks in space, regardless of how much navigational experience they have, which is also proposed by Evans et al. (1981). Because the absolute position of landmarks in space is more difficult to obtain, people need more navigational experience to use this category of navigation ability. While the results for navigational experience on the allocentric location-based navigation task were as expected, there was a very small effect size. This means that the effect of navigational experience on allocentric location-based navigation was not very large, which could be caused by the large sample size of this study. There was no significant main effect found for living area on each navigation task. That living area had no influence on navigation ability could be because nowadays there is greater mobility and people, either from urban living areas or rural living areas, travel more than in former times. A lot has changed since the range size hypothesis was proposed (Jones et al., 2003). It is possible that this greater mobility is the reason why in this study living area had no impact on each task of the navigation experiment.

The framework of Siegel and White (1975) proposes that navigation ability develops through stages and that survey knowledge is the most sophisticated category to obtain and acquires experience. Our findings argue against this, since all participants performed just as well on the survey knowledge path-based navigation task, regardless of navigational experience. On the route knowledge path-based navigation task there was a trend towards a significant interaction effect and this shows that there was a difference in scores, influenced by both living area and navigational experience. Participants with more navigational experience performed slightly better if they lived in an urban environment, while participants with less navigational experience performed better if they lived in a rural environment. However, the effect size of this effect was again very small. Therefore we cannot not assume that the effect of living area and navigational experience was very big on route knowledge path-based navigation. What we can assume is that navigational experience is not necessary to perform well on the route knowledge and survey knowledge path-based navigation tasks and that the developmental progression through the stages proposed by Siegel and White (1975) is not necessary. The reason for these contrasting results could be because Siegel and White (1975) used a very small sample in comparison with a large heterogeneous sample in our study.

Besides the strengths of having a large heterogeneous sample and using a well-developed navigation experiment, the current study had some limitations as well. First of all the fact that participants could do the experiment at home, which makes it questionable if all the participants were serious in doing the experiment. This could limit the reliability of the results. To ensure that this was not the case, we excluded all the participants who did not finish the experiment, but there is still a chance that some participants did not do the experiment in all seriousness. Second, the effect sizes of the results were very small, which means that the effect of living area and navigational experience on navigation ability was not very big. The reason for the small effect sizes could be the very large, heterogeneous sample. The possibility exists that no significant effects will be found within a smaller sample. Finally, participants with higher education (VWO/WO) were relatively more represented in urban environments compared to rural environments. The reason for this could be that higher education is most likely given in bigger cities and thus urban environments. We did not use education as a covariate in our analyses, but it is possible that education was of influence on our results.

Given all of the above, future studies should take these limitations into account. We used age as a covariate in our analyses, but it might be interesting to have a similar study where different age groups are tested separately to see if living area and navigational experience have a different influence on navigation ability in different age groups. There is a good possibility that younger participants travel a lot more and thus have more navigational experience than older participants, which could cause them to have better navigation scores in general. There is also a possibility that older participants more often live in rural environments in comparison with younger participants. Besides, the possibility exists that people with higher education more often live in urban environments because of their work or study. A study that takes education into account would be very interesting to see if education has an impact on navigational experience and navigation ability. Additionally, a similar study with a more controlled testing environment together with more controlled questions about navigational experience and living area could be a good solution to enlarge the reliability of the study. On top of that, it might be interesting to use a smaller, homogeneous sample to see if those results are similar to our findings.

Despite the limitations of this study, our results suggests that there are different categories of navigation ability which can vary among people. Previous studies have already shown that navigation ability consists of landmark, route and survey knowledge. This study shows that navigation ability also consists of allocentric and egocentric location knowledge and that it can vary among people with and without navigational experience. Assessment of navigation ability should therefore include tasks with landmark-based, location-based and path-based navigation, especially for people with navigation impairment. This will give a better view of the categories that are affected and the ones that are still intact. Knowledge about this may enhance treatment programs. Additionally, navigational experience had an impact on some aspects of navigation ability in our study. This has important implications for the treatment of navigation impairment as well. Travelling once a year or more can already enhance the allocentric location-based navigation ability and the overall navigation ability. Using a virtual training game were patients with navigation impairment are exposed to different environments might improve several aspects of navigation ability.

In conclusion, the main aim of this study was to assess whether navigational experience and living area were of influence on navigation ability. We have demonstrated that navigation ability does vary among people and that navigational experience contributes to these differences. People with more experience have a better allocentric location-based navigation ability and overall navigation ability. Moreover, living area does not contribute to the differences in navigation ability among people, which could be influenced by greater mobility nowadays. The difference between people in mobility could be the reason for the differences in navigation ability. Future work taking mobility into account and using more controlled testing environments and different age groups may give a better understanding of the influence of navigational experience on navigation ability.

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